PACIFIC OCEAN PERCH

by

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Executive Summary

A review of the available data for eastern Bering Sea/Aleutian Islands (BSAI) Pacific ocean perch (POP), and a series of potential population models, was presented to the Plan Team and discussed at the September, 2001, meeting. The Plan Team concluded that a single BSAI model was appropriate, in contrast to the separate AI and EBS models presented in previous assessments. Motivations for this change includes the paucity of data in the EBS upon which to base an age-structured assessment, and uncertainty that the EBS POP represent a discrete stock. In the combined model the fishery harvest levels, and the fishery age and length compositions, are computed for the entire BSAI area, and the Aleutian Islands survey is used as an index of abundance. The historical EBS slope surveys are not used. The following changes in input data and assessment methodology were also made:

Changes in the Input Data

(1) Fishery age composition data from 1977-1982 was included in the model.

(2) EBS fishery length composition data from 1977,1981,1984,1995, and 1998 were included in the model.

(3) The 2000 harvest level have been revised and harvests through October 13, 2001 have been included in the assessment.

(4) The 2000 age compositions from the AI fishery and survey were included in the assessment.

Changes in the Assessment Methodology

(1) In years in which length and age compositions are available, the age composition was generally used and the length composition dropped from the analysis. However, only the length compositions were used for years 1963-1972, as the age compositions were derived from scale readings.

(2) The recruitment strengths of the cohorts present in the first year of the model were individually estimated rather than assumed constant.

(3) The foreign and domestic fishery is modeled with a single selectivity curve.

Changes in the Assessment Results

(1) A summary of the 2001 ABC's relative to the 2000 recommendations is as follows (the 2000 results are the sum from the separate eastern Bering Sea and Aleutian Islands models):

	Assessment Year	
	2000	2001
ABC	11,940 t	14,776 t
OFL	13,885 t	17,510 t

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INTRODUCTION

Pacific ocean perch (*Sebastes alutus*) inhabit the outer continental shelf and upper slope regions of the North Pacific Ocean and Bering Sea. In previous assessments, the management of Pacific ocean perch (POP) in these areas has been divided into two geographic units corresponding to the eastern Bering Sea slope and the Aleutian Islands region. POP biomass in the Aleutian Islands (AI) region is larger than that in the eastern Bering Sea (EBS) region.

Pacific ocean perch, and four other associated species of rockfish (northern rockfish, *S. polyspinis*; rougheye rockfish, *S. aleutianus*; shortraker rockfish, *S. borealis*; and sharpchin rockfish, *S. zacentrus*) were managed as a complex in the two distinct areas from 1979 to 1990. Known as the POP complex, these five species were managed as a single entity with a single TAC (total allowable catch). In 1991, the North Pacific Fishery Management Council enacted new regulations that changed the species composition of the POP complex. For the eastern Bering Sea slope region, the POP complex was divided into two subgroups: 1) Pacific ocean perch, and 2) shortraker, rougheye, sharpchin, and northern rockfishes combined, also known as "other red rockfish." For the Aleutian Islands region, the POP complex was divided into three subgroups: 1) Pacific ocean perch, 2) shortraker/rougheye rockfishes, and 3) sharpchin/northern rockfishes. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, and rougheye rockfish (the three most valuable commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual TAC.

Of the five species which comprise the POP complex, *S. alutus* has historically been the most abundant rockfish in this region and has contributed most to the commercial rockfish catch. Furthermore, the bulk of the research on rockfish has been concentrated on *S. alutus*; relatively little biological or assessment information is available for the other rockfish species. This chapter discusses strictly Pacific ocean perch; the assessment of other red rockfish is addressed in another chapter.

For this years assessment, a combined BSAI POP model is used. Motivations for this change includes the paucity of data in the EBS upon which to base an age-structured assessment, and uncertainty that the EBS POP represent a discrete stock (Spencer and Ianelli 2001). The most recent EBS slope survey was conducted in 1991, and the available EBS slope survey biomass estimates are plagued with high coefficients of variation. Additionally, the available evidence does not clearly resolve the question of whether the EBS POP should be considered a distinct stock separate from the AI POP.

FISHERY

Pacific ocean perch were highly sought by Japanese and Soviet fisheries and supported a major trawl fishery throughout the 1960s. Catches in the eastern Bering Sea peaked at 47,000 (metric tons, t) in 1961; the peak catch in the Aleutian Islands region occurred in 1965 at 109,100 t. Apparently, these stocks were not productive enough to support such large removals. Catches continued to decline throughout the 1960s and 1970s, reaching their lowest levels in the mid 1980s. With the gradual phase-out of the foreign fishery in the 200-mile U.S. Exclusive Economic Zone (EEZ), a small joint-venture fishery developed but was soon replaced by a domestic fishery by 1990. In 1990 the domestic fishery recorded the highest Pacific ocean perch removals since 1977. The history of *S. alutus* landings since implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) is shown in Table 1.

Estimates of retained and discarded Pacific ocean perch from the fishery have been available since 1990. Table 2 summarizes this information for *S. alutus* in both regions. The eastern Bering Sea region generally shows a higher discard rate than in the Aleutian Islands region. For the period from 1990 to 1999, the Pacific ocean perch discard rate in the eastern Bering Sea averaged about 24.5%; whereas, in the Aleutian Islands region, the discard rate for the same period averaged about 16.7%. The removals from trawl and hydoracoustic surveys are shown in Table 3.

There has been little change in the distribution of observed Aleutian Islands POP catch from the foreign and joint venture fisheries (years 1977-1988) and the domestic fishery (years 1990-2000) with respect to fishing depth and management area. The fishing depth accounting for the largest proportion of catch in each fishery was 200-299 m, with 49% and 66% of the observed foreign/joint venture and domestic catch, respectively (Table 4). Management area 541 contributes the largest share of the observed catch in each fishery; with 46% and 43% in the foreign/joint venture and domestic fisheries, respectively (Table 5). Note that this is in contrast to the year 2000 fishery, in which area 543 contributes the largest share of the catch. Area 543 contributed a large share of the catch in the late 1970s foreign fishery , as well as the domestic fishery from the mid-1990s to the present. In the late 1980s to the early 1990s, area 541 contributed a large share of the catch. Note that the proportions of total POP caught that were actually sampled by observers was very low in the foreign fishery, due to low sampling ratio prior to 1984 (Megrey and Wespestad 1990).

DATA

Fishery Data

Catch per unit effort (CPUE) data from Japanese trawl fisheries indicate that Pacific ocean perch stock abundance has declined to very low levels in the Aleutian Islands region (Ito 1986). By 1977, CPUE values had dropped by more than 90-95% from those of the early 1960s. Japanese CPUE data after 1977, however, is probably not a good index of stock abundance because most of the fishing effort has been directed to species other than Pacific ocean perch. Standardizing and partitioning total groundfish effort into effort directed solely toward Pacific ocean perch is extremely difficult. Increased quota restrictions, effort shifts to different target species, and rapid improvements in fishing technology undoubtedly affect our estimates of effective fishing effort. Consequently, we included CPUE data primarily to evaluate its consistency with other sources of information. We used nominal CPUE data for class 8 trawlers in the eastern Bering Sea and Aleutian Islands regions from 1968-1979. During this time period these vessels were known to target on Pacific ocean perch (Ito 1982).

Length measurements and otoliths read from the EBS and AI management areas were combined to create fishery age/size composition matrices (Table 6). In previous models for EBS POP model, no fishery length composition data was used between 1973 and 1989 due to small sample sizes. Length composition data from these years are now included by adding to the more numerous observations from the AI fishery. In addition, fishery otoliths from 1977 to 1982 were not included in the model, and were added this year. In 1982, the method for aging otoliths at the Alaska Fisheries Science Center changed from surface reading to the break and burn method (Betty Goetz, Alaska Fisheries Science Center, pers. comm.), as the latter method is considered more accurate for older fish (Tagart 1984). The time at which the otoliths collected from 1977 to 1982 were read is not known for many vessels and cruises. However, the information available suggests that otoliths from 1977 to 1980 were read prior to 1981, whereas otoliths from 1981 and 1982 were read after 1982.

Survey Data

Because the Aleutian Islands survey spans two management areas, that portion of the survey from longitude 165 W to 170 W was used only the in EBS model in previous assessments. With the combined model, the entire survey biomass from the Aleutian Islands survey was used as an index of abundance. Note that there is wide variability among survey estimates from the portion of the Aleutian Islands survey in the EBS, with the estimated biomass increasing from 1501 t in 1991 to 18, 217 t in 1994; the 2000 estimate is 18,870 t (Table 7). The estimated biomass of Pacific ocean perch in the Aleutian Islands region (long. 170° W to 170° E) appears to be less variable. For the entire survey area, there has been a steady increase from 1980 to 1997, followed by a decline to the 2000 estimate. The 1991 trawl survey produced a biomass estimate of 351,093 t, more than three times the 1980 point estimate. The 1994 and 1997 trawl surveys produced biomass estimates of 383,618 and 625,272 t. The most recent trawl survey of the Aleutian Islands region occurred in 2000 and produced an estimate of 511,706 t. Age composition data exists for each survey year, as otoliths sampled in the 2000 survey have been added to the model. The length measurements and otoliths read from the Aleutian Islands surveys are shown in Table 8.

In the combined BSAI POP model, the EBS slope survey is dropped altogether, due to the high CVs, the lack of recent surveys, and the relatively small population size compared to the Aleutian Islands biomass estimates. These survey were conducted in 1979, 1981, 1982, 1985, 1998, 1991; the surveys from 1979 to 1985 were cooperative U.S.-Japan trawl surveys, whereas in 1988 and 1991 the surveys were conducted primarily by NMFS personnel. The cooperative survey vessels sampled depths from 200-1000 m, whereas the 1988 and 1991 surveys sampled depths from 200-800 m. In 2001, the POP biomass in all slope surveys was re-estimated using the strata developed for the 1988 and 1991 surveys, thus not using the stations from 800-1000 m. The re-estimation produced similar estimates as those previously obtained, an expected result because POP are not often found between 800 and 1000 m (Spencer and Ianelli 2001). The re-estimation also produced high coefficients of variation (CV), averaging 0.43 over the six surveys. These high CVs have engendered uncertainty regarding the extent to which survey trends represent population trends, and thus motivated use of an average biomass over the survey years (including also the portion of the Aleutian Islands survey in the EBS management area) in previous assessments.

The following table summarizes the data available for the BSAI POP model:

Component	BSAI
Fishery catch	1960-2001
Fishery age composition	1977-82, 1990,1998
Fishery size composition	1964-72, 1983-1984,1987-1989,1991-1997,1999-2000
Fishery CPUE	1968-79
Survey age composition	1980, 83, 86, 91, 94, 97, 2000
Survey biomass estimates	1980, 83, 86, 91, 94, 97, 2000

Biological Data

The surveys produce large numbers of samples for age determination, length-weight relationships, sex ratio information, and for estimating the length distribution of the population. The age compositions were determined by constructing age-length keys for each year and using them to convert the observed length frequencies from each year. Because the survey age data were based on the break and burn method of ageing Pacific ocean perch, they were treated as unbiased but measured with error.

Kimura and Lyons (1991) give data on the percent agreement between otolith readers for Pacific ocean perch. The estimate of aging error was identical to that presented in Ianelli and Ito (1991). The assessment model uses this information to create a transition matrix to convert the simulated "true" age composition to a form consistent with the observed but imprecise age data.

Assessments of Pacific ocean perch have significantly changed in the past decade because of improved methods of age determination. Previously, Pacific ocean perch age determinations were done using scales and surface readings from otoliths. These gave estimates of natural mortality of about 0.15 and a longevity of about 30 years (Gunderson 1977). Based on the now accepted break and burn method of age determination using otoliths, Chilton and Beamish (1982) determined the maximum age of *S. alutus* to be 90 years. Using similar information, Archibald et al. (1981) concluded that natural mortality for Pacific ocean perch should be on the order of 0.05.

Growth curves used in previous assessments were based upon survey data from the 1980s. In this assessment, all available survey data was used to estimate von Bertalannfy growth curves. This consisted of years 1980, 1983, 1986, 1991, 1994, and 1997 for the Aleutian Islands, and years 1981, 1982, and 1991 for the eastern Bering Sea. The resulting growth curves parameters were very similar to those used in previous assessments, and are:

	Aleutian Islands	**Eastern Bering Sea**
L_{inf}	40.09	40.38
K	0.1629	0.1323
t_0	0.72855	1.7766

There is little difference in the growth curves between areas, or in the estimated growth curves within an area over time. Growth information from the Aleutian Islands was used to convert estimated numbers at age within the model to estimated numbers at length.

The estimated length(cm)-weight(g) relationship for Aleutian Islands POP were also re-estimated with all available survey information. For the eastern Bering Sea, fishery data from 1975 to 1999 were used to estimate the length-weight relationship, as individual weights were not recorded in the EBS surveys. The resulting length-weight relationships, where weight = a*(length)^b, were similar between regions:

	Aleutian Islands	**Eastern Bering Sea**
a	1.054×10^{-5}	8.59×10^{-6}
b	3.08	3.13

Again, there was little difference between areas, or between years in a single area. The Aleutian Islands length-weight relationship was used to produce estimated weights at age. A combined-sex model was used, as the ratio of males to females varied slightly from year to year but was not significantly different from 1:1 (Ianelli and Ito 1991). The proportion mature at age schedule used is identical to that used in the Gulf of Alaska POP assessment.

ANALYTIC APPROACH

The POP assessment model was implemented with the AD Modelbuilder software program, thus converting the model from the previous implementation in the stock-synthesis program. A discussion of this conversion process can be found in Spencer and Ianelli (2001). Several changes were made in model assumptions, affecting primarily the numbers at age in the first year and the fishery selectivity curve.

Model Structure

An age-structured population dynamics model was used to obtain estimates of recruitment, numbers at age, and catch at age. Population size in numbers at age *a* in year *t* was modeled as

$$N_{t,a} = N_{t-1,a-1} e^{-Z_{t-1,a-1}} \qquad 3 \le a < A, \quad 1960 \le t \le T$$

where Z is the sum of the instantaneous fishing mortality rate ($F_{t,a}$) and the natural mortality rate (M), A is the maximum number of age groups modeled in the population (defined as 25), and T is the terminal year of the analysis (defined as 2001). The numbers at age A are a "pooled" group consisting of fish of age A and older, and are estimated as

$$N_{t,A} = N_{t-1,A-1} e^{-Z_{t-1,A-1}} + N_{t-1,A} e^{-Z_{t-1,A}}$$

The numbers at age in the first year are estimated as

$$N_a = R_0 e^{-M(a-3)+\gamma_a}$$

where R_0 the number of age 3 recruits for an unfished population and γ is an age-dependant deviation assumed to be normally distributed with mean of zero and a standard deviation equal to σ, the recruitment standard deviation. The previous stock synthesis model estimated the first year numbers at age to be in equilibrium with an historical catch of 400 t, and required estimation of a historic fishing mortality rate parameter. The equilibrium assumption implied that the recruitment strengths of all cohorts in the first year were equivalent, whereas the estimation of the vector of age-dependant deviations from average recruitment allows estimation of year class strength.

The total numbers of age 3 fish from 1960 to 1994 are estimated as parameters in the model, and are modeled with a lognormal distribution

$$N_{t,3} = e^{(\mu_R + \nu_t)}$$

where ν is a time-variant deviation. The recruitments from 1995 to 2001 are set the median recruitment, e^{μ_r}.

The fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of a fishery age-specific selectivity (*fishsel*) and a year-specific fully-selected fishing mortality rate f. The fully selected mortality rate is modeled as the product of a mean (μ_f) and a year-specific deviation (ϵ_t), thus $F_{t,a}$ is

$$F_{t,a} = fishsel_a * f_t \equiv fishsel_a * e^{(\mu_f + \varepsilon_t)}$$

In previous assessments two fishery selectivity curves were modeled, one for the foreign fishery

(1960-1988) and one for the domestic fishery (1989-present). Given the similarity between the two fisheries in terms of depth and management area fished (Tables 4 and 5), a single fishery selectivity curve was used. A double logistic fishery selectivity curve has historically been used in BSAI POP assessments, as an asymptotic selectivity pattern for the fishery previously found to be inadequate in describing the observed data (Ianelli and Ito 1992). However, fishery selectivity curves in recent years have shown sharp declines in over a small range of older ages, implying unusually large selectivity differences in fish of quite similar size and age. In this model, a series of selectivity curves were evaluated, including the asymptotic logistic curve, the dome-shaped double logistic, and a double logistic curve that penalizes sharp differences between adjacent ages.

The mean numbers at age for each year was computed as

$$\overline{N}_{t,a} = N_{t,a} * (1 - e^{-Z_{t,a}}) / Z_{t,a}$$

The predicted length composition data were calculated by multiplying the mean numbers at age by a transition matrix, which gives the proportion of each age (rows) in each length group (columns); the sum across each age is equal to one. Twenty-five length bins were used, ranging from 15 cm to 39+ cm. The transition matrix was based upon an estimated von Bertalanffy growth relationship, with the variation in length at age interpolated from between the first and terminal ages in the model.

Both unbiased and biased age distributions are used in the model. For unbiased age distributions, aging imprecision is inferred from studies indicating that the percent agreement between readers varies from 60% for age 3 fish to 13% for age 25 fish (Kimura and Lyons 1991). The information on percent agreement was used to derive the variability of observed age around the “true”age, assuming a normal distribution. The mean number of fish at age available to the survey or fishery is multiplied by the aging error matrix to produce the observed survey or fishery age compositions. Similarly, estimated biased age distributions are computed by multiplying the mean number of fish at age by a biased aging error matrix, which was derived from data in Tagart (1984).

Catch biomass at age was computed as the product of mean numbers at age, instantaneous fishing mortality, and weight at age. The predicted trawl survey biomass (*pred_biom*) was computed as

$$pred\_biom_t = qsurv \sum_a \left(\overline{N}_{t,a} * survsel_a * W_a \right)$$

where W_a is the population weight at age, $survsel_a$ is the survey selectivity, and *qsurv* is the trawl survey catchability. We use the Aleutian Islands trawl survey biomass estimates in a relative sense rather than in an absolute sense by allowing *qsurv* to be estimated in the model rather than fixed at 1.0. Similarly, the predicted catch per unit effort index was computed as

$$pred\_cpue_t = qcpue \sum_a \left(\overline{N}_{t,a} * fishsel_a * W_a \right)$$

where *qcpue* is the scaling factor for the CPUE index.

Parameters Estimated Independently

The parameters estimated independently include the biased and unbiased age error matrices, the age-length transition matrix, individual weight at age, and natural mortality. The age error matrices were obtained from information in Kimura and Lyons (1991) and Tagart (1984), and are identical to those used in the previous assessments. The age-length transition matrix was derived from the updated von Bertalanffy growth parameters. The individual weights at age were updated, based on the fitted von Bertalanffy model and length-weight relationships. The natural mortality rate *M* was fixed at 0.05, consistent with studies on POP age determination (Chilton and Beamish 1982, Archibald et al. 1981).

Parameters Estimated Conditionally

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the age and length composition of the survey and fishery catch, the survey biomass, and the catch biomass. The general approach is to assume that deviations between model estimates and observed quantities are attributable to observation error and can be described with statistical distributions. Each data component provides a contribution to a total log-likelihood function, and parameter values that maximize the log-likelihood are selected.

The log-likelihood of the initial recruitments were modeled with a lognormal distribution

$$\lambda_1 \sum_t \frac{\left(\nu_t + \frac{\sigma^2}{2}\right)^2}{2\sigma^2} + n\ln(\sigma)$$

The adjustment of adding $\sigma^2/2$ to the deviation was made in order to produce deviations from the mean, rather than the median, recruitment.

The log-likelihoods of the fishery and survey age and length compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) for the fishery length composition data, with the addition of a term that scales the likelihood, is

$$n_{f,t,l} \sum_{s,t,l} p_{f,t,l} \ln(\hat{p}_{f,t,l}) - p_{f,t,l} \ln(p_{f,t,l})$$

where *n* is the square root of the number of fish measured, and $p_{f,t,l.}$ and $\hat{p}_{f,t,l}$ are the observed and estimated proportion at length in the fishery by year and length. The likelihood for the age and length proportions in the survey, $p_{surv,t,a}$ and $p_{surv,t,l}$, respectively, follow similar equations.

The log-likelihood of the survey biomass was modeled with a lognormal distribution:

$$\lambda_2 \sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2cv_t^2$$

where obs_biom_t is the observed survey biomass at time *t*, cv_t is the coefficient of variation of the survey biomass in year *t*, and λ_2 is a weighting factor. The log-likelihood of the CPUE index is computed in a similar manner, and is weighted by λ_3. The log-likelihood of the catch biomass was modeled with a lognormal distribution:

$$\lambda_4 \sum_t (\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

where obs_cat_t and $pred\_cat_t$ are the observed and predicted catch. Because the catch biomass is generally thought to be observed with higher precision that other variables, λ_4 is given a very high weight so as to fit the catch biomass nearly exactly. This can be accomplished by varying the *F* levels, and the deviations in *F* are not included in the overall likelihood function. The overall negative log-likelihood function (excluding the catch component) is

$$
\begin{aligned}
&\lambda_1\left(\sum_t\left(\frac{\nu_t+\sigma^2/2}{2\sigma^2}\right)^2+n\ln(\sigma)\right)+\\
&\lambda_2\sum_t(\ln(obs\_biom_t)-\ln(pred\_biom_t))^2/2*cv_t^2+\\
&\lambda_3\sum_t(\ln(obs\_cpue_t)-\ln(pred\_cpue_t))^2/2*cv_{CPUE}^2+\\
&n_{f,t,l}\sum_{s,t,l}p_{f,t,l}\ln(\hat{p}_{f,t,l})-p_{f,t,l}\ln(p_{f,t,l})+\\
&n_{f,t,a}\sum_{s,t,l}p_{f,t,a}\ln(\hat{p}_{f,t,a})-p_{f,t,a}\ln(p_{f,t,a})+\\
&n_{surv,t,a}\sum_{s,t,a}p_{surv,t,a}\ln(\hat{p}_{surv,t,a})-p_{surv,t,a}\ln(p_{surv,t,a})+\\
&n_{surv,t,l}\sum_{s,t,a}p_{surv,t,l}\ln(\hat{p}_{surv,t,l})-p_{surv,t,l}\ln(p_{surv,t,l})+\\
&\lambda_4\sum_t(\ln(obs\_cat_t)-\ln(pred\_cat_t))^2
\end{aligned}
$$

For the model run in this analysis, λ_1, λ_2, λ_3, and λ_4 were assigned weights of 1,1, 0.5, and 500, reflecting a de-emphasis of the CPUE index and strong emphasis on fitting the catch data. The sample sizes for the age and length compositions were set to the square root of the number of fish. The negative log-likelihood function was minimized by varying the following parameters (assuming a double logistic fishery selectivity curve):

Parameter type	Number
1) fishing mortality mean (μ_f)	1
2) fishing mortality deviations (ϵ_t)	42
3) recruitment mean (μ_r)	1
4) recruitment standard deviation (σ)	1
5) recruitment deviations (ν_t)	35
6) historic recruitment (R_0)	1
7) first year recruitment deviations	22
8) Biomass survey catchability	1
9) CPUE index catchability	1
10) fishery selectivity parameters	4
11) survey selectivity parameters	2
Total parameters	111

RESULTS

Model Selection

Three separate models were evaluated that differed with respect how the fishery selectivity curve was modeled. In Model 1, the fishery selectivity curve was modeled with the double logistic function, as in previous assessments:

$$fishsel_a = \frac{1}{(1 + e^{-aslope(l-afifty)})(1 + e^{-dslope(l-dfifty)})}$$

where the parameters *aslope* and *dslope* affects the ascending and descending steepness of the curve and the parameter *afifty* and *dfifty* is the age at which selectivity equals 0.5. In Model 2, the double logistic curve is also used but a penalty that is related to the differences in selectivity between ages is added to the log likelihood. This is accomplished by taking the second difference of the log selectivity

$$sel\_penalty = \lambda_5 \sum_{a=5}^{a=25} (\{\ln(sel_a) - \ln(sel_{a-1})\} - \{\ln(sel_{a-1}) - \ln(sel_{a-2})\})^2$$

where the penalty weighting factor λ_5 was set to 40. In Model 3, the asymptotic logistic curve was used for selectivity.

The likelihood components for the three models are shown in Table 9, and the estimated fishery and survey selectivities are shown in Figure 1. The double logistic curve produces the lowest negative log-likelihood, but marked by a sharply declining curve at older ages. For example, 23 year old POP show twice the selectivity of those 24 years old (0.54 to 0.26). Adding the selectivity penalty smoothes the curve, but reduces the number of ages for which POP would be fully selected and increases the age at 50% selectivity on the ascending limb from 7.25 to 8.14. With an asymptotic curve, the age at 50% selectivity is lowered to 6.64. The asymptotic curve produces a higher negative log likelihood than either of the other two curves, with differences occurring primarily in the recruitment, unbiased fishery age composition, and survey age composition components. However, the fit to the fishery length composition is improved. Much of the higher negative log likelihood comes from older ages in the earlier fishery (1981,1982) and survey (1980-1986) age composition data, as the fits to the more recent age composition data are similar to those with the double logistic curve. Although the asymptotic logistic curve does not produce the lowest negative log-likelihood, it does produce: 1) an overall reasonable fit to the data (particularly recent age compositions); 2) an easily interpretable fishery selectivity pattern; and 3) more conservative estimates of total biomass. For these reasons the logistic curve (Model 3) is used to produce the results below, although evaluation of alternative fishery selectivity curves should proceed in the future.

Biomass Trends

The estimated survey biomass index begins with 806,906 t in 1960, declines to 114,178 t in 1978, and increases to 518,318 t in 2001 (Figure 2). The reader should bear in mind that the survey point estimates are used in a relative sense rather than in an absolute sense, with a survey catchability (q) estimated at 1.53 rather than fixed at 1.0. Because the Aleutian Islands survey biomass estimates are taken as an index for the entire BSAI area, it is reasonable to expect that the q would be below 1.0 to the extent that the total BSAI biomass is higher than the Aleutian Islands biomass. Thus, although q is lower than in last years Aleutian Islands POP assessment, where it was estimated as 2.06, it is still higher than expected. One factor that may cause an increase in survey catchability is the expansion of survey trawl estimates to untrawlable areas (Kreiger and Sigler 1996). The fit to the CPUE index is shown in Figure 3.

The total biomass showed a similar trend as the survey biomass, with the 2001 total biomass estimated as 373,807 t. The estimated time series of total biomass, spawning biomass, and recruitment are given in Table 10. The estimated total biomass for recent years in this years assessment is considerably higher than in the 2000 assessment, in part to the change in survey q. The estimated numbers at age are shown in Table 11.

Age/size compositions

The fishery age compositions, biased and unbiased, are shown in Figures 4 and 5 respectively. As noted above, the observed proportion in the binned age 25+ group for years 1981 and 1982 is higher than the estimated proportion, although the fits improve in recent years (Figure 5). The fishery length compositions are shown in Figure 6; some of the lack of fit in the mid- to late-1980s is attributable to the low sample size of lengths observed from a reduced fishery. The survey age compositions (Figure 7) show a similar pattern as the unbiased fishery age compositions in that the age 25+ group is fit better in recent years (1994-2000) than earlier years (1980-1986).

Fishing Mortality

The estimates of instantaneous fishing mortality for POP range from highs during the 1970’s to low levels in the 1980’s (Fig. 8). Relative to the estimated $F_{35\%}$ level, the stocks in both the eastern Bering Sea and Aleutian Islands were overfished during considerable portions of this period (Figure 8). Fishing mortality rates since the early 1980's, however, have moderated considerably due to the phase out of the foreign fleets and quota limitations imposed by the North Pacific Fishery Management Council. The average fishing mortality from 1965 to 1980 was 0.25, whereas the average from 1981 to 2001 was 0.03.

Recruitment

For both the eastern Bering Sea and Aleutian Islands, year class strength varies widely (Figure 9; Table 10). The relationship between spawning stock and recruitment also displays a high degree of variability (Figure 10). The 1962 year class is particularly large, more than twice any other estimated recruitment. Recruitment appears to be lower in early 1990s than in the mid-1980s, but the recent observations are based upon cohorts which have not been extensively observed in the available data.

Projections and Harvest Alternatives

The reference fishing mortality rate for Pacific ocean perch is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{0.40}$, $F_{0.35}$, and $SPR_{0.40}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1977-1998 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{0.40}$ is calculated as the product of $SPR_{0.40}$ * equilibrium recruits, and this quantity is 140,660 t. The year 2002 spawning stock biomass is estimated as 134,694 t. Since reliable estimates of the 2002 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B<B_{0.40}$ (134,694 t > 140,660 t), POP reference fishing mortality is defined in tier 3b. For this tier, F_{ABC} is constrained to be $\leq F_{0.40}$, and F_{OFL} is constrained to be $\leq F_{0.35}$; the values of $F_{0.40}$ and $F_{0.35}$ are 0.0480 and 0.057, respectively. Under the guidelines of tier 3b of Amendment 56, we calculate the F_{ABC} as $\{F_{0.40}$ x $(SPB_{2002}/SPB_{0.40}$ - 0.05)/(1-0.05)}. This procedure produces an F_{ABC} of 0.046 and an ABC estimate for the Aleutian Islands region of approximately 14,766 t. This ABC is approximately 2800 t higher than last years combined EBS and AI recommendation of 11,940 t. The estimated catch level for year 2002 associated with the overfishing level of F = 0.055 is 17,510 t. A summary of these values is below.

2002 SSB estimate (B)	=	134,694 t
$B_{0.40}$	=	140,660 t
$F_{0.40}$	=	0.048
F_{ABC}	=	0.046
$F_{0.35}$	=	0.057
F_{OFL}	=	0.055

Projections and Harvest Alternatives

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2001 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2002 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2001. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2002, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2002 recommended in the assessment to the *max* F_{ABC} for 2002. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1996-2000 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and five-year projections of the mean spawning stock biomass, fishing mortality rate, and harvest for the remaining four scenarios are shown in Table 12.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Pacific ocean perch stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2002, then the stock is not overfished.)

Scenario 7: In 2002 and 2003, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2004 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the BSAI Pacific ocean perch stock is neither overfished or approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2002 of scenario 6 is 1.10 times its $B_{35\%}$ value of 123,077 t. With regard to whether Pacific ocean perch is likely to be overfished in the future, the expected stock size in 2004 of scenario 7 is 1.07 times the $B_{35\%}$ value.

OTHER CONSIDERATIONS

This combination of the eastern Bering Sea and Aleutian Islands management areas motivates consideration of the criteria to be used to divide the ABC among the areas. One option is to use the proportional survey biomass from the two management areas to partition the ABCs. The average biomass from 1991-2000 in the AI management area is 455,251 t, whereas the average from the southern Bering Sea is 12,671 t; thus 97% of the estimated Aleutians Islands survey biomass occurs in the Aleutian Islands management area. Because the Aleutian Islands survey does not cover the EBS slope, the average of recent catches from the two management areas may be more appropriate. The average catch from the AI management area from 1998-2000 is 9,836 t, whereas the average from the EBS management area is 616 t (Table 1); thus 94% of the estimated catch in the last three years has come from the Aleutian Islands management area. The use of recent average catch to partition the ABC is recommended here, and would divide the overall ABC of 14,776 t to 13,889 t in the Aleutian Islands and 887 t in the eastern Bering Sea.

As in previous years, it is recommended that the Aleutians Islands portion of the ABC be partitioned among management subareas in proportion to the estimated biomass. The four most recent trawl surveys (1991, 1994, 1997,and 2000; Table 13), indicate that the average POP biomass was distributed in the Aleutian Islands region as follows:

	Biomass (%)
Eastern subarea (541):	28.4%
Central subarea (542):	25.1%
Western subarea (543):	46.5%
Total	100%

Under these proportions, the recommended ABCs are 3,944 t for area 541, 3,486 t for area 542, and 6,458 t for area 543.

FUTURE RESEARCH OBJECTIVES

In future assessments, further evaluation of fishery and survey selectivity curves may prove worthwhile, including alternatives to the logistic and double logistic curves. The new eastern Bering Sea slope survey, beginning in 2002, will help with partitioning the ABC among regions and should be included into the assessment model as soon as feasible.

SUMMARY

The management parameters for Pacific ocean perch as presented in this assessment are summarized as follows:

M	0.05
$F_{35\%}$	0.057
$F_{40\%}$	0.048
Equil. spawner biomass ($F_{40\%}$)	140,660 t
2002 spawner biomass	134,694 t
$F_{abc\ (adjusted)}$	0.046
ABC (adjusted $F_{40\%}$)	14,776 t
$F_{overfishing}$ (adjusted $F_{35\%}$)	0.055
Overfishing Level	17,510 t

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Table 1. Estimated removals of Pacific ocean perch (*S. alutus*, t) since implementation of the Magnuson Fishery Conservation and Management Act of 1976.

	Eastern Bering Sea			Aleutian Islands			BSAI
Year	Foreign	JVP	DAP	Foreign	JVP	DAP	Total catch
1977	2,654	--	--	8,080	--	--	10,734
1978	2,221	--	--	5,286	--	--	7,507
1979	1,723	--	--	5,487	--	--	7,210
1980	1,050	47	--	4,700	Tr	--	5,797
1981	1,221	1	--	3,618	4	--	4,844
1982	212	3	8	1,012	2	--	1,237
1983	116	97	7	272	8	--	500
1984	156	134	1,122	356	273	2	2,043
1985	35	32	629	Tr	215	72	983
1986	16	117	375	Tr	160	98	766
1987	5	50	768	0	500	391	1,714
1988	0	51	874	0	1,513	362	2,800
1989	0	31	2,570	0	Tr	2,101	4,702
1990	0	0	6,344	0	0	11,838	18,182
1991	0	0	5,339	0	0	2,831	8,170
1992	0	0	3,309	0	0	10,278	13,587
1993	0	0	3,746	0	0	13,330	17,076
1994	0	0	1,687	0	0	10,865	12,552
1995	0	0	1,207	0	0	10,303	11,510
1996	0	0	2,855	0	0	12,827	15,682
1997	0	0	817	0	0	12,648	13,465
1998	0	0	1,017	0	0	9,051	10,068
1999	0	0	381	0	0	11,880	12,261
2000	0	0	451	0	0	8,577	9,028
2001*	0	0	784	0	0	7,924	8,708

Tr = trace, JVP = Joint Venture Processing, DAP = Domestic Annual Processing.
Source: PacFIN, NMFS Observer Program, and NMFS Alaska Regional Office.
Estimated removals through October 13, 2001.

Table 2. Estimated retained and discarded catch (t), and percent discarded, of Pacific ocean perch from the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions.

	EBS			AI			BSAI		
Year	Retained	Discarded	Percent Discarded	Retained	Discarded	Percent Discarded	Retained	Discard	Percent Discarded
1990	5,069	1,275	20.10	10,288	1,551	13.10	15,357	2,826	15.54
1991	4,112	1,227	22.98	1,851	980	34.62	5,963	2,207	27.01
1992	2,784	525	15.87	8,686	1,592	15.49	11,470	2,117	15.58
1993	2,602	1,144	30.54	11,438	1,892	14.19	14,040	3,036	17.78
1994	1,281	406	24.07	9,491	1,374	12.65	10,772	1,780	14.18
1995	839	368	30.49	8,603	1,700	16.50	9,442	2,068	17.97
1996	2,522	333	11.66	9,832	2,995	23.35	12,354	3,328	21.22
1997	539	278	34.03	10,855	1,793	14.18	11,394	2,071	15.38
1998	821	201	19.67	8,030	940	10.48	8,851	1,141	11.42
1999	247	134	35.17	10,406	1,473	12.40	10,653	1,607	13.11
2000	229	221	49.11	7,844	734	8.56	8,073	955	10.58
2001*	377	408	51.97	6,585	1,339	16.90	6,962	1,747	20.06

*Estimated removals through October 13, 2001.
Source: NMFS Alaska Regional Office

Table 3. Estimated catch (t) of Pacific ocean perch in Aleutian Islands and eastern Bering Sea trawl surveys, and the eastern Bering Sea hydroacoustic survey.

		Area	
Year	AI	BS	BS-Hydroacoustic
1977		0.01	
1978		0.13	0.01
1979		3.08	
1980	71.47	0.00	
1981		13.98	
1982	0.24	12.09	
1983	133.30	0.16	
1984		0.00	
1985		98.57	
1986	164.54	0.00	
1987		0.01	
1988		10.43	
1989		0.00	
1990		0.02	0.01
1991	73.57	2.76	0.00
1992		0.38	0.00
1993		0.01	0.00
1994	112.79	0.00	0.02
1995		0.01	0.01
1996		1.18	0.00
1997	177.94	0.73	0.15
1998		0.01	0.00
1999		0.19	0.00
2000	140.82	22.90	0.45
2001		0.11	

Table 4. Proportional catch (by weight) of Aleutians Islands POP in the foreign/joint venture fisheries and the domestic fishery by depth.

Depth	Foreign and JV (1977-1988)	Domestic (1990-2000)
0-99	0.03	0.00
100-199	0.34	0.20
200-299	0.49	0.66
300-399	0.13	0.12
400-499	0.01	0.01
500-599	0.00	0.00
≥501	0.00	0.00
Observed catch	1,638	81,755
Total Catch	31,486	114,428
Sampling ratio	0.05	0.71

Table 5. Proportional catch (by weight) of Aleutians Islands POP in the foreign and joint venture fisheries and the domestic fishery by management area.

Area	Foreign and JV (1977-1988)	Domestic (1990-2000)
541	0.46	0.43
542	0.27	0.23
543	0.26	0.33
Observed catch	1,638	81,755
Total Catch	31,486	114,428
Sampling ratio	0.05	0.71

Table 6. Length measurements and otoliths read from the EBS and AI POP fisheries, from Chikuni (1975) and NORPAC Observer database.

	Length Measurements			Otoliths read		
Year	EBS	AI	Total	EBS	AI	Total
1964	24,150	55,599	79,749			
1965	14,935	66,120	81,055			
1966	26,458	25,502	51,960			
1967	48,027	59,576	107,603			
1968	38,370	36,734	75,104			
1969	28,774	27,206	55,980			
1970	11,299	27,508	38,807			
1971	14,045	18,926	32,971			
1972	10,996	18,926	29,922			
1973	1		1**			
1974	84		84**	84		84**
1975	1		1**	125		125**
1976	50		50**	114	19	133**
1977	1,059	2,778	3,837*	139	404	543
1978	7,926	7,283	15,209*	583	641	1,224
1979	1,045	10,921	11,966*	248	353	601
1980		3,995	3,995*		398	398
1981	1,502	7,167	8,669*	78	432	510
1982		4,902	4,902*		222	222
1983	232	441	673			
1984	1,194	1,210	2,404	72		72**
1985	300		300**	160		160**
1986		100	100**		99	99**
1987	11	384	395	11		11**
1988	306	1,366	1,672			
1989	957	91	1,048		19	19**
1990	22,228	47,198	69,426*	144	184	328
1991	8,247	8,221	16,468			
1992	13,077	24,932	38,009			
1993	8,379	26,433	34,812			
1994	2,654	11,546	14,200			
1995	272	11,452	11,724			
1996	2,967	13,146	16,113			
1997	143	10,402	10,545			
1998	989	11,106	12,095*		823	823
1999	289	3,839	4,128			
2000	284	3,382	3,666		487	487

*Used to create age composition.
**Not used.

Table 7. Pacific ocean perch estimated biomass (t) from the Aleutian Islands trawl surveys, by management area.

	Southern Bering Sea			Aleutian Islands			Total Aleutian Islands Survey		
Year	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
1979									
1980	6003	9966	1.66	109022	27670	0.25	115025	29410	0.26
1981									
1982									
1983	97478	89947	0.92	144080	26338	0.18	241558	93723	0.39
1984									
1985									
1986	49562	29214	0.59	220614	39909	0.18	270176	49459	0.18
1987									
1988									
1989									
1990									
1991	1501	758	0.51	349592	79318	0.23	351093	79322	0.23
1992									
1993									
1994	18217	11685	0.64	365401	87600	0.24	383618	88376	0.23
1995									
1996									
1997	12099	7008	0.58	613174	96405	0.16	625272	96659	0.15
1998									
1999									
2000	18870	10150	0.54	492836	89535	0.18	511706	90109	0.18

Table 8. Length measurements and otoliths read from the Aleutian Islands surveys.

Year	Length measurements	Otoliths read
1980	20796	872
1983	22873	2299
1986	14804	1860
1991	14262	807
1994	18922	788
1997	22823	1172
2000	21972	1219

Table 9. Negative log likelihood fits of various model components for BSAI POP models with a double logistic fishery selectivity curve (Model 1), a double logistic fishery selectivity curve that penalize non-smoothness (Model 2), and a asymptotic fishery selectivity curve (Model 3).

Likelihood component	**Model 1**	**Model 2**	**Model 3**
Recruitment	-0.962	-6.677	16.442
AI survey biomass	2.766	2.542	2.608
CPUE	10.668	11.533	11.807
Catch	0.012	0.024	0.007
Fishing mortality penalty	8.301	8.744	6.783
fishery biased age comps	2.926	3.721	3.899
fishery unbiased age comps	23.231	19.072	32.191
fishery length comps	187.797	201.024	176.910
AI survey age comps	32.238	32.390	49.886
selectivity penalty	0.000	10.078	0.000
parameters	111	111	109
- ln likelihood	266.977	282.451	300.532

Table 10. Estimated time series of POP total biomass (t), spawner biomass (t), and recruitment (thousands) for each region. The 2000 results are the sum of the separate EBS and AI models.

	Total Biomass (ages 3+)		Spawner Biomass (ages 3+)		Recruitment (age 3)	
	Assessment		Assessment		Assessment	
Year	2001	2000	2001	2000	2001	2000
1962	601,283	799,010	155,647	292,357	46,643	115,697
1963	612,558	789,702	182,277	288,605	27,952	47,243
1964	602,030	753,600	195,628	271,890	156,690	65,736
1965	542,277	668,213	172,645	232,984	455,961	344,295
1966	453,248	560,171	136,712	190,718	25,505	72,599
1967	382,434	470,287	101,957	154,386	38,268	42,515
1968	344,614	411,644	78,492	126,321	101,485	54,642
1969	297,994	348,613	63,212	107,083	25,246	43,384
1970	268,735	307,965	57,982	92,164	25,060	61,746
1971	208,724	239,512	45,988	76,120	25,510	43,948
1972	191,893	216,148	46,375	67,506	24,948	34,243
1973	164,602	184,295	43,186	59,029	27,590	30,730
1974	159,688	175,271	45,659	54,292	23,178	20,859
1975	131,885	143,702	39,054	45,669	26,811	23,171
1976	114,257	122,417	34,508	38,413	20,615	16,731
1977	92,354	96,748	27,159	31,690	21,286	17,460
1978	89,991	91,068	25,760	29,238	39,144	33,775
1979	94,512	94,342	25,543	27,737	74,110	87,309
1980	101,320	102,205	25,399	26,509	68,579	100,035
1981	114,282	113,752	25,762	25,771	99,329	86,953
1982	126,675	124,141	26,935	25,871	35,570	30,996
1983	144,154	140,679	30,353	28,042	48,145	56,618
1984	171,521	164,470	34,914	31,638	156,756	118,363
1985	193,448	182,105	40,641	36,470	42,992	29,620
1986	217,675	206,860	47,443	42,436	60,440	105,304
1987	247,986	231,896	55,701	50,016	131,036	80,544
1988	274,097	253,950	66,051	59,391	57,101	49,354
1989	301,966	276,771	76,160	68,197	102,071	80,521
1990	325,377	294,691	86,196	76,339	56,501	45,827
1991	334,410	298,891	92,313	81,511	71,489	67,458
1992	349,786	309,185	101,520	88,259	34,115	27,243
1993	356,264	310,867	109,123	93,380	24,905	21,722
1994	355,332	305,947	114,587	97,143	18,090	18,866
1995	359,016	304,980	121,585	101,922	58,848	39,997
1996	362,706	303,718	127,824	105,197	58,848	39,898
1997	361,420	297,177	130,930	106,219		
1998	362,244	292,334	133,460	106,948		
1999	366,081	290,224	136,101	107,329		
2000	368,123	285,887	136,691	106,383		
2001	373,807		138,172			

Table 12. Projections of BSAI spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 140,660 t and 123,077 t, respectively.

Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2001	135196	135196	135196	135196	135196	135196	135196
2002	134694	134694	135466	134952	136243	134402	134694
2003	133426	133426	137243	134683	141208	132012	133426
2004	132453	132453	139194	134633	146517	130030	132171
2005	131759	131759	141304	134796	152150	128427	130464
2006	131837	131837	144122	135695	158684	127674	129604
2007	131747	131747	146677	136388	165001	126849	128673
2008	131954	131954	149463	137347	171610	126399	128124
2009	132477	132477	152518	138610	178544	126335	127989
2010	132974	132974	155448	139826	185318	126319	127861
2011	133647	133647	158498	141211	192217	126534	127952
2012	134277	134277	161408	142536	198913	126758	128060
2013	134988	134988	164326	143928	205580	127099	128235
2014	135580	135580	167011	145174	211915	127359	128380
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2001	0.0371598	0.0371598	0.0371589	0.0371592	0.037159	0.0371598	0.0371588
2002	0.0458206	0.0458206	0.0229103	0.03816	0	0.0545275	0.0458206
2003	0.0453652	0.0453652	0.0232254	0.03816	0	0.0535043	0.0453653
2004	0.0450161	0.0450161	0.0235714	0.03816	0	0.0526557	0.0535721
2005	0.0447671	0.0447671	0.0239455	0.03816	0	0.0519697	0.0528417
2006	0.0447952	0.0447952	0.0239809	0.03816	0	0.0516472	0.0524735
2007	0.0447628	0.0447628	0.0239809	0.03816	0	0.0512937	0.0520749
2008	0.0448369	0.0448369	0.0239809	0.03816	0	0.0511013	0.0518397
2009	0.0450187	0.0450187	0.0239809	0.03816	0	0.0510738	0.0517777
2010	0.0451692	0.0451692	0.0239809	0.03816	0	0.0510651	0.0517092
2011	0.0453465	0.0453465	0.0239809	0.03816	0	0.0511467	0.0517203
2012	0.0454704	0.0454704	0.0239809	0.03816	0	0.0512216	0.0517343
2013	0.0455912	0.0455912	0.0239809	0.03816	0	0.0513366	0.0517719
2014	0.0456716	0.0456716	0.0239808	0.03816	0	0.0514142	0.0518012
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2001	11940.6	11940.6	11940.3	11940.4	11940.3	11940.6	11940.2
2002	14776.3	14776.3	7470.69	12351.6	0	17510.2	14776.4
2003	14632.5	14632.5	7738.86	12441.7	0	17048.3	14633.1
2004	14512.7	14512.7	8006.12	12514.4	0	16651.5	17209.4
2005	14445	14445	8287.05	12596.2	0	16347.5	16897.7
2006	14530.3	14530.3	8479.73	12726.9	0	16245.2	16778.4
2007	14591.8	14591.8	8649.69	12848.2	0	16140.6	16637.6
2008	14701.4	14701.4	8820.56	12976.2	0	16111.5	16571.1
2009	14863.5	14863.5	8996.38	13116.3	0	16161.3	16593
2010	14999.4	14999.4	9157.16	13239.9	0	16207.4	16592.5
2011	15147.4	15147.4	9316.37	13365.4	0	16291.5	16632
2012	15261.9	15261.9	9461.87	13476.3	0	16361.3	16668.5
2013	15380.7	15380.7	9606.95	13591.4	0	16452.9	16709.8
2014	15468.1	15468.1	9736.91	13689.4	0	16514.9	16748.9

Table 13. Pacific ocean perch biomass estimates (t) from the 1991, 1994, 1997, and 2000 triennial trawl surveys broken out by the three management sub-areas in the Aleutian Islands region.

	Aleutian Islands Management Sub-Areas		
Year	Western	Central	Eastern
1991	214,137	79,911	55,545
1994	184,005	80,811	100,585
1997	225,725	166,816	220,633
2000	222,584	129,740	140,512
Average	211,613	114,319	129,319
Percentage	46.5%	25.1%	28.4%

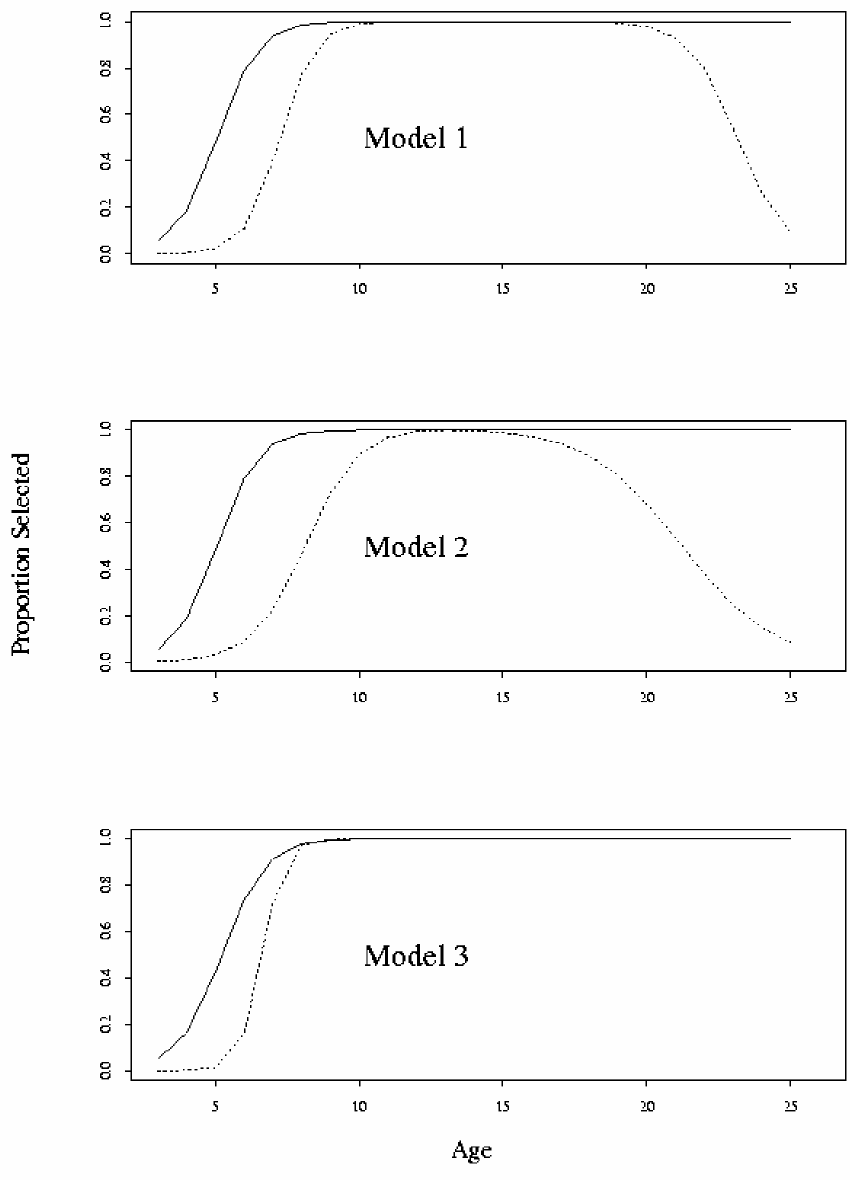

Figure 1. Estimated survey (solid line) and fishery selectivity (dashed line) for three potential models of BSAI POP.

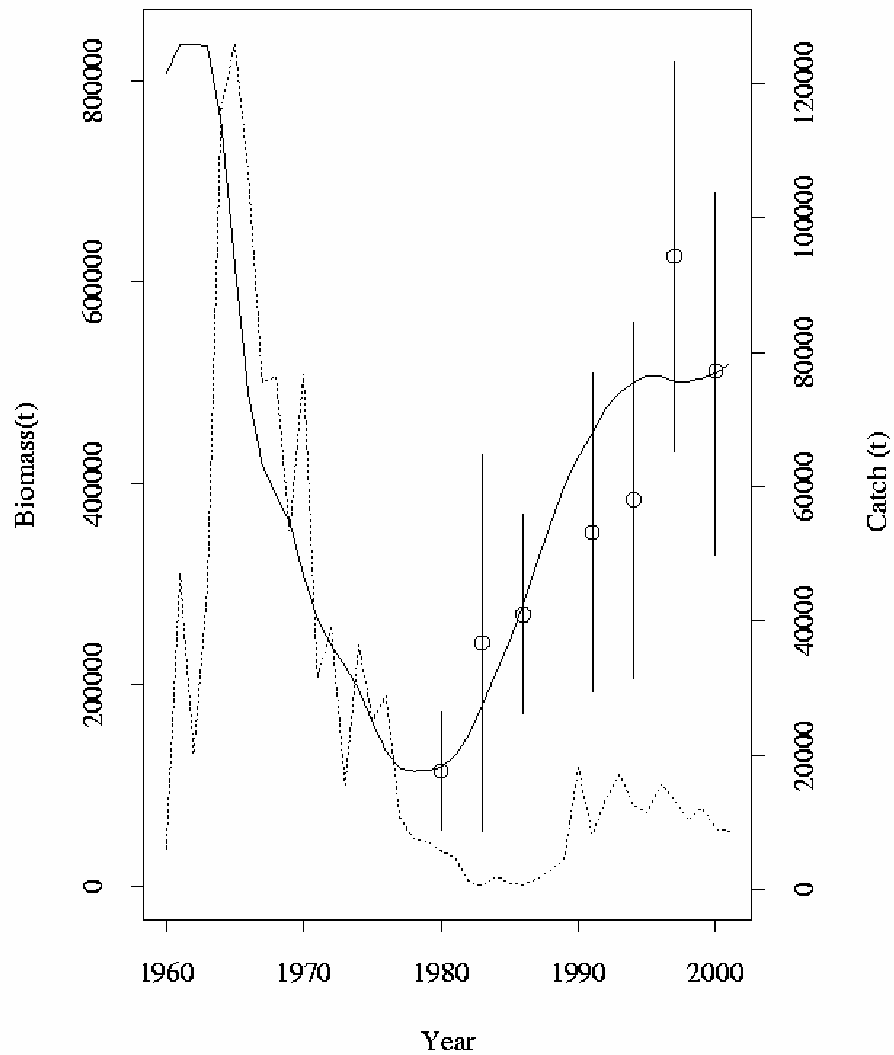

Figure 2. Observed AI survey biomass(data points, +/- 2 standard deviations), predicted survey biomass(solid line), and BSAI harvest (dashed line).

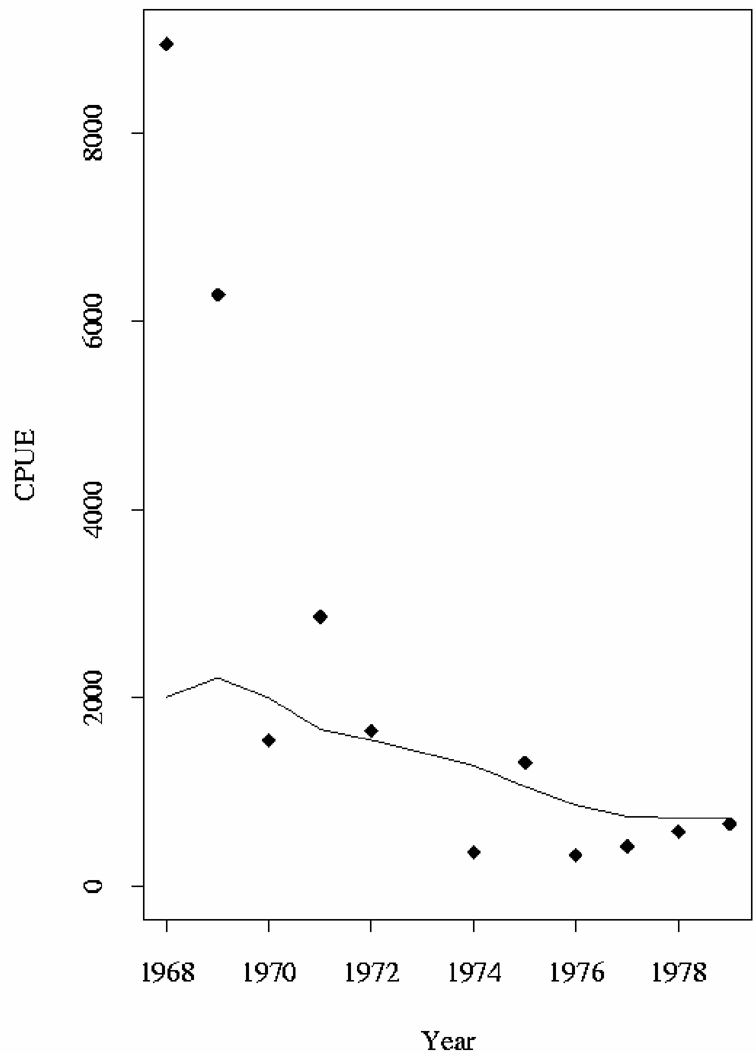

Figure 3. Observed AI CPUE (data points) and predicted CPUE (solid line) for BSAI POP.

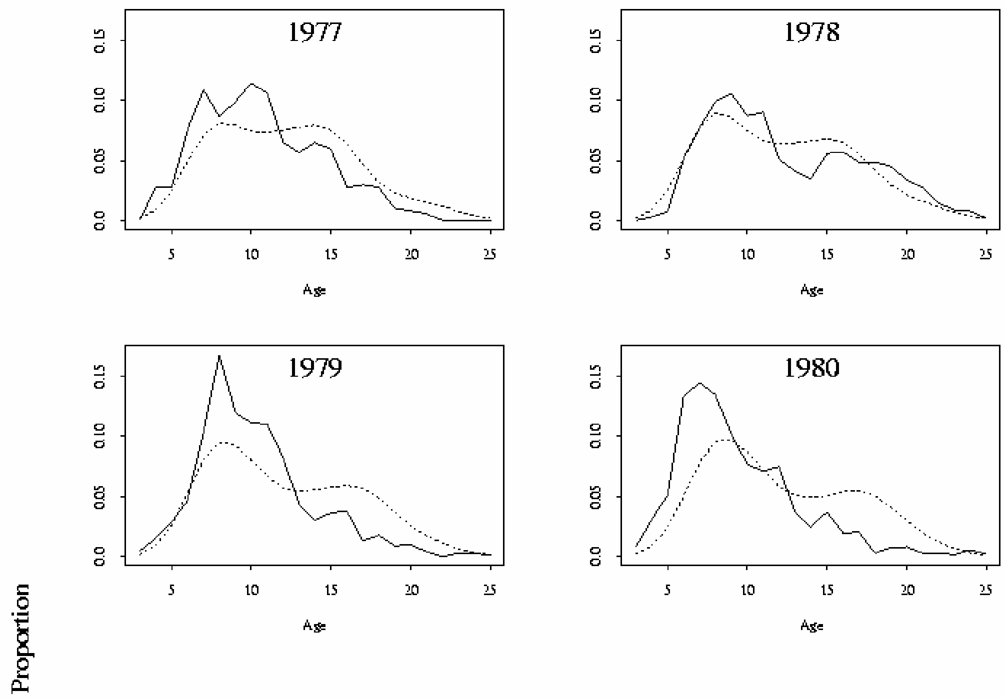

Figure 4. Fishery biased age composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

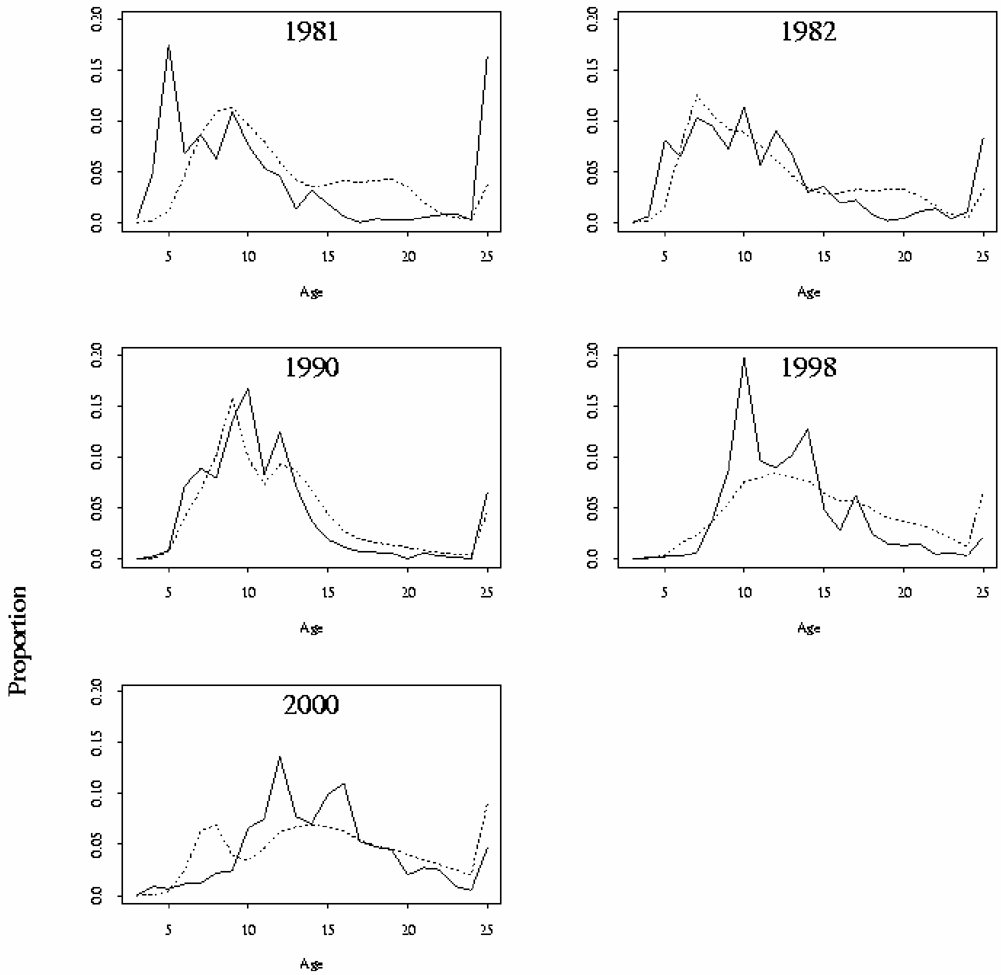

Figure 5. Fishery age composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

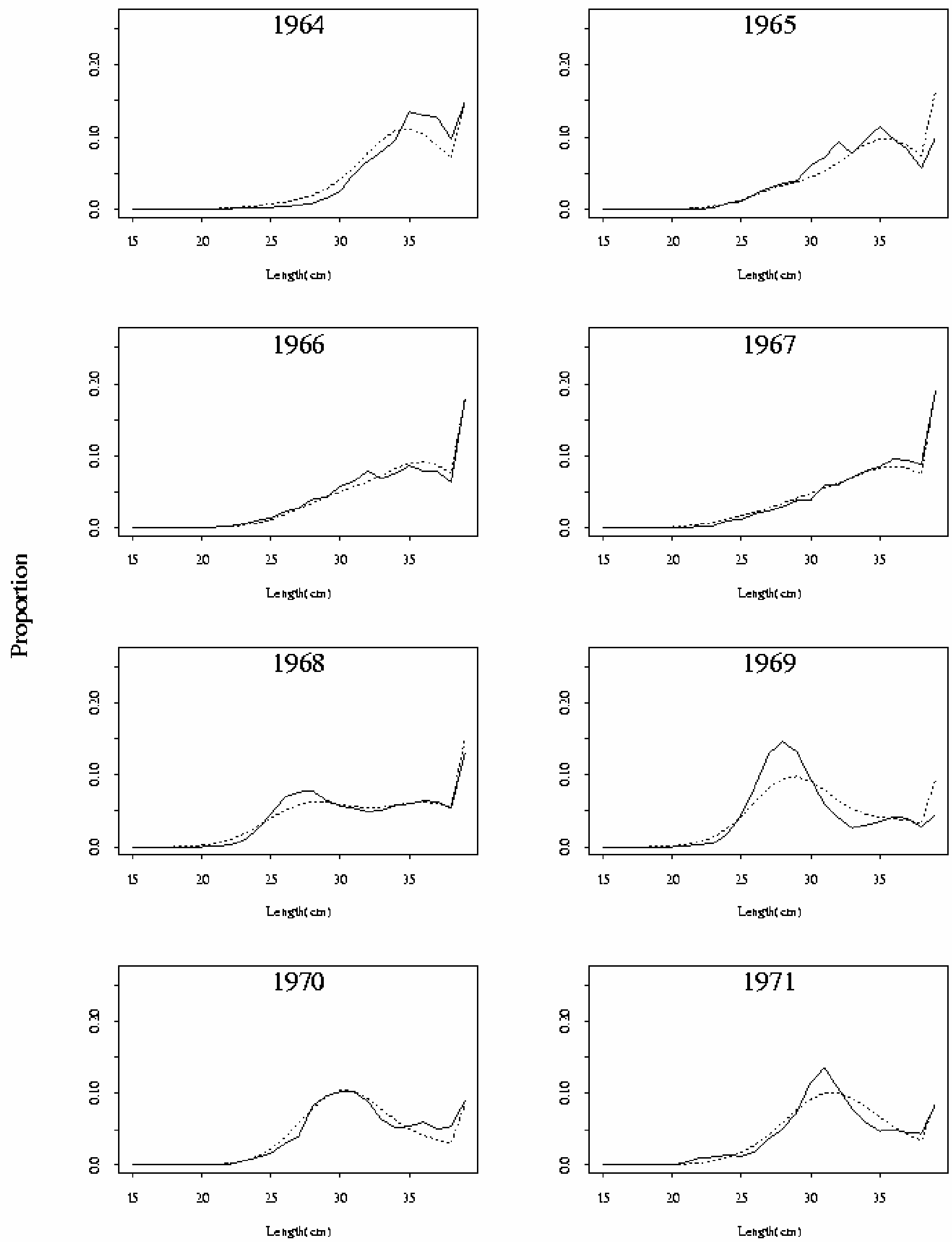

Figure 6. Fishery length composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

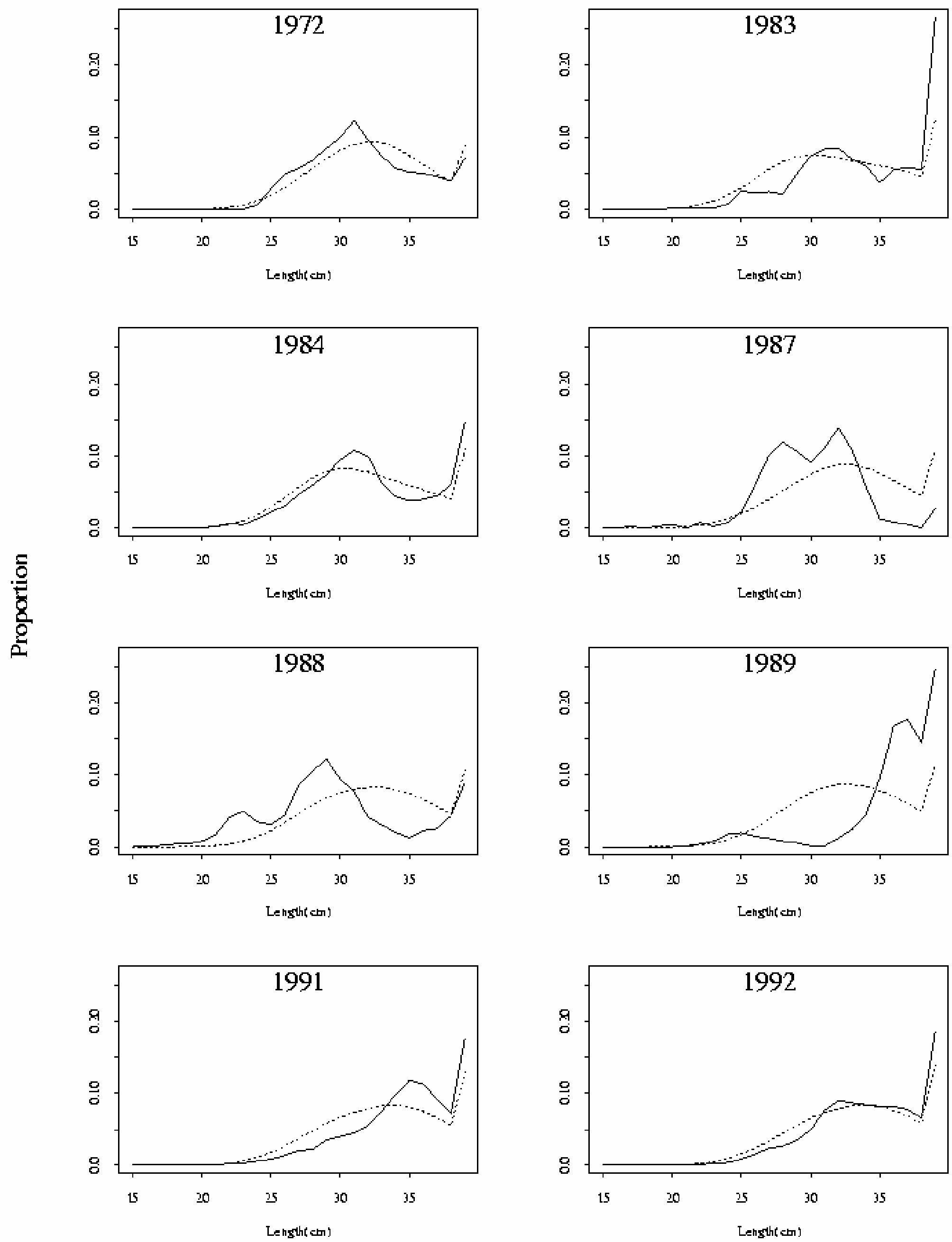

Figure 6. Fishery length composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

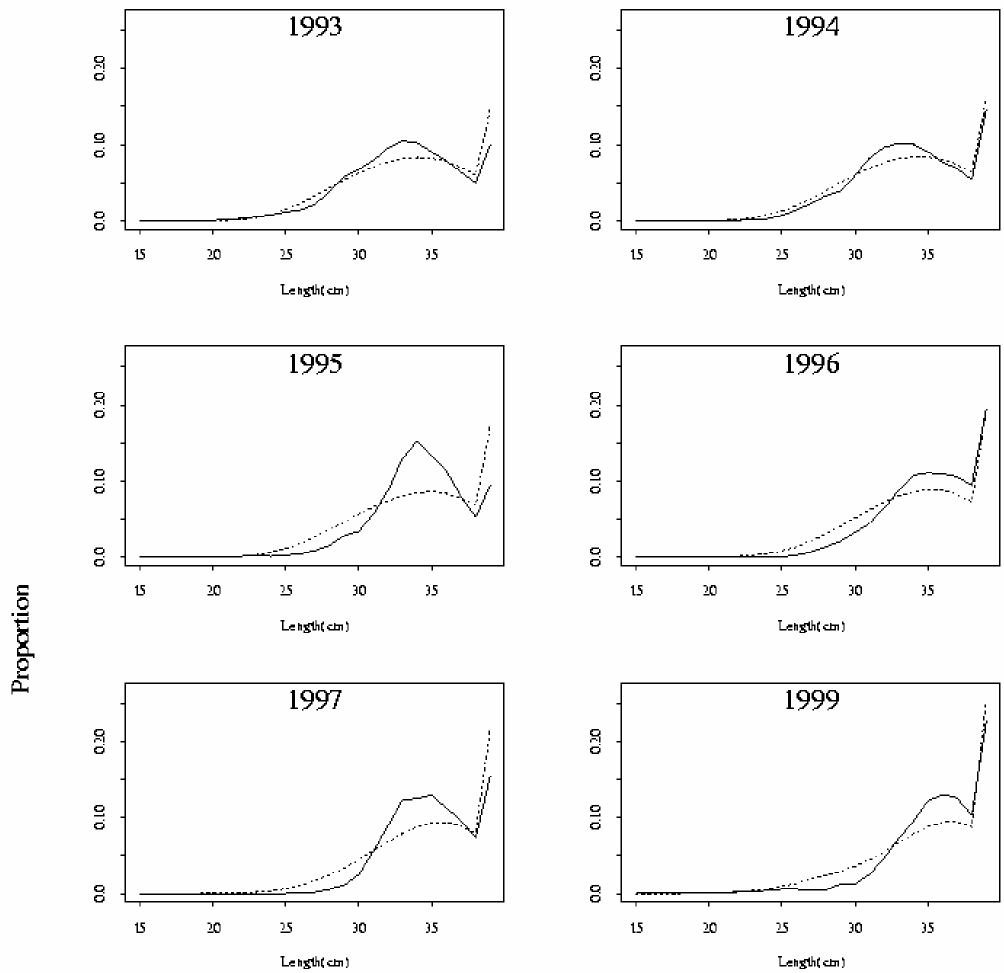

Figure 6. Fishery length composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

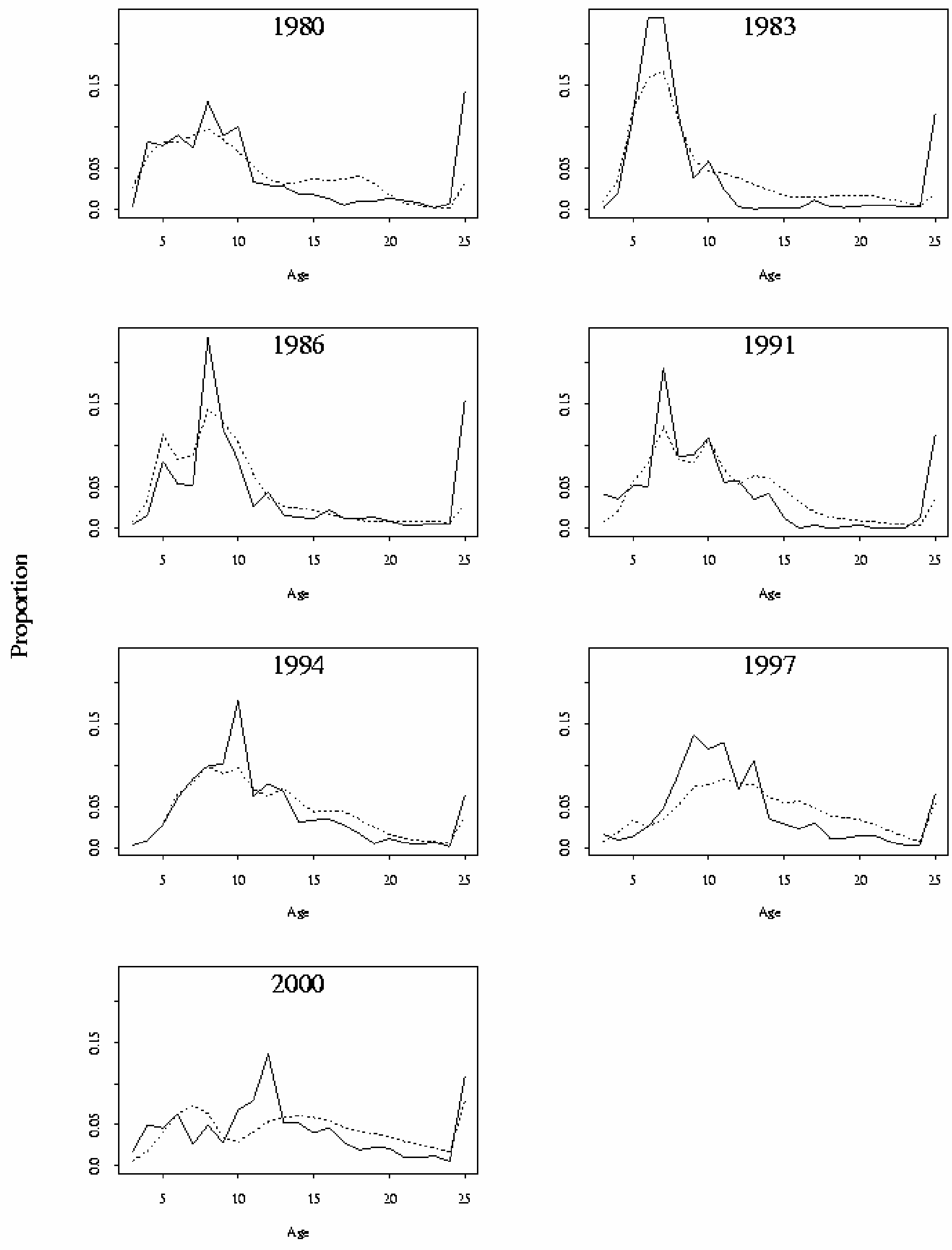

Figure 7. AI Survey age composition by year (solid line = observed, dotted line = predicted) from BSAI POP.

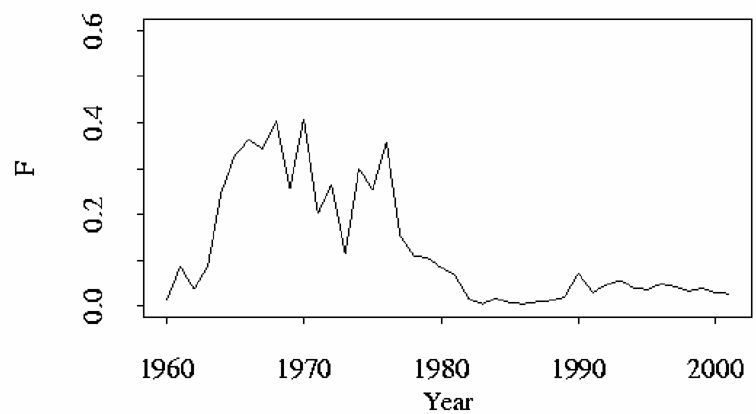

Figure 8. Estimated fully selected fishing mortality for BSAI POP.

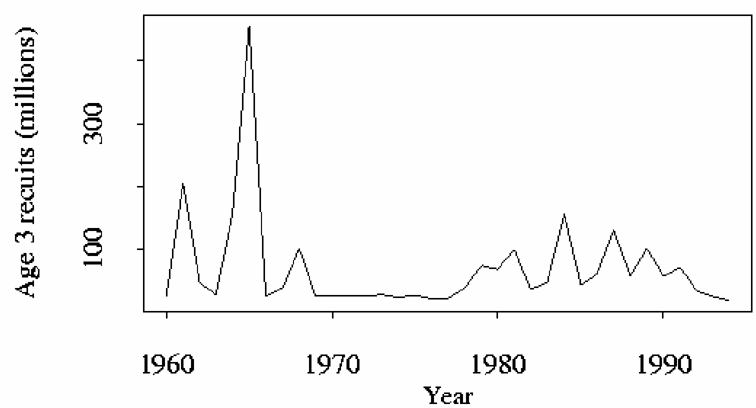

Figure 9. Estimated recruitment (age 3) of BSAI POP.

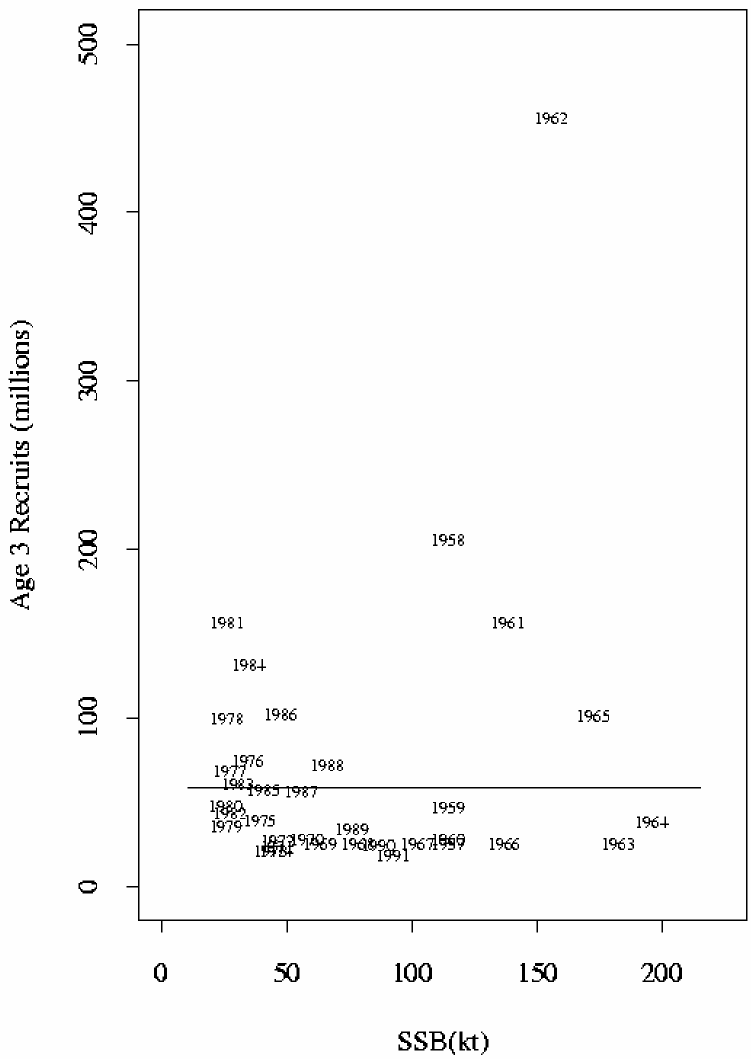

Figure 10. Scatterplot of BSAI POP spawner-recruit data; label is year class.